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The desert of northern Baja California

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(WITH TWO TEXT FIGURES)

The peninsula of Lower California is one of the most thinly settled and poorly explored portions of North America, outside the Arctic regions. The aridity of the climate and the absence of generous sources of water has retarded the development of even such small areas as might have agricultural value. With an area nearly half as great as that of the State of California, the peninsula has a population of only 42,000. With the scarcity of settlements in the interior and the absence of roads, the exploration of Lower California has been chiefly along the coast. An expedition led by E. A. Goldman and E. W. Nelson in 1905–06, under the auspices of the Biological Survey, covered the peninsula more thoroughly than earlier workers had been able to do, and resulted in the most important publications that have appeared on the distributional and ecological aspects of the vegetation.

The plant and animal life of Lower California bears many resemblances to the biota of Southern California and of the mainland of Sonora and Sinaloa. In the central and southern part of the peninsula, however, there are many endemic forms, indicating the long duration of practically insular conditions of isolation. In addition to many striking species of palms, yuccas, cacti and desert trees and shrubs, the flora of the peninsula contains a number of plants of unusual form and habit, calculated to give zest to the exploration of every mountain range and valley. There is the procumbent giant cactus, *Lemaireocereus eruca*, the large and richly branched *Fouquiera peninsularis*, as well as the closely related *Idria columnaris*, with stout, abruptly tapering stem, two branching arborescent species of *Nolina*, and several

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trees in which the diameter of the greatly thickened trunk is out of all proportion to the height.

A broken series of mountain ranges runs through the entire length of Lower California, with several low passes connecting the outwash slopes of the Pacific Coast with the narrower slopes that face the Gulf of California. The highest elevation is Santa Catarina Peak, 10,135 feet in elevation, in the San Pedro Martir Mountains, 125 miles south of the International Boundary. Other ranges further south reach elevations of 5000 to 8000 feet. From the northern base of the San Jacinto Mountains, in Southern California, to the southern end of the San Pedro Martir range there is a series of elevations almost continuously above 5000 feet, and extending parallel to the Pacific Coast for 300 miles. In the lee of these mountains is one of the most arid parts of America north of the equator. Rain is confined to the winter and early spring months, and falls only when rain on the coast or in the mountains is accompanied by winds of considerable strength and duration.

In November, 1924, three members of the staff of the Desert Laboratory made a short expedition from the Salton Basin down the eastern coast of Lower California to a locality nearly opposite the southern end of the San Pedro Martir Mountains. A little-used road was followed as far as San Felipe Bay, from which place a short excursion to the south and interior was made on foot. The preceding summer had been an unusually dry one throughout the lower basin of the Colorado River, and the preceding winter had also been deficient in rainfall. The region was seen, therefore, in a condition such as to give an adequate conception of the conditions which must be met by the plants and animals of this extreme desert.

After crossing the International Boundary at Mexicali our route lay across the irrigated alluvial lands which share in the water of the Colorado River that is taken out by the Imperial Canal. The sole crop here is cotton, which produces a heavy yield from large perennating plants. On emerging from the irrigated lands the Cucopa Mountains lie on the right, and on the left the delta of the Colorado River. This part of the delta has a heavy stand of cottonwood (*Populus Macdougali*), mesquite (*Prosopis glandulosa*), arrow weed (*Pluchea sericea*), and salt bush (*Atriplex spp.*). The narrow bajada of the mountains is

covered with a very open stand of *Covillea*, infrequent individuals of *Parkinsonia*, and with numerous plants of *Isocoma veneta*. The only other perennials are the two cacti *Opuntia echinocarpa* and *O. ramosissima*, and infrequent plants of *Asclepias subulata*.

The bajada of the Cucopa Mountains becomes very narrow on passing southward and finally vanishes at El Mayor, where Hardy's Colorado cuts the base of the mountains. From this locality the Hardy flows in a southeasterly direction, its flow

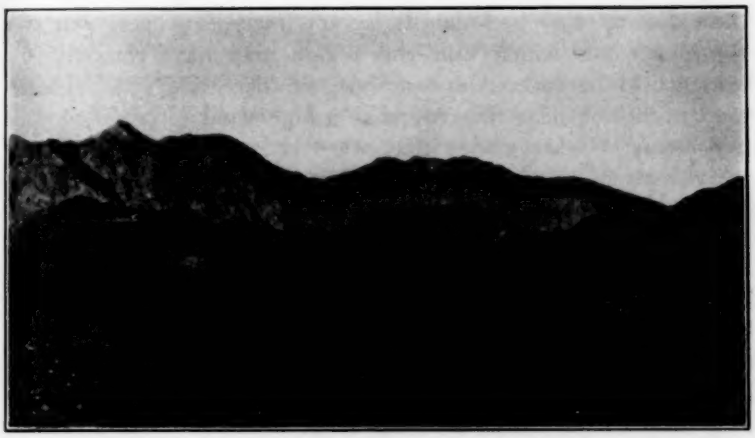

FIG. 1. Eastern slopes of the Cucopa Mountains at El Mayor, showing barren slopes and bajada with sparse stand of *Covillea*.

soon becoming subject to tidal influence. South of El Mayor is an extensive tidal flat which borders the Hardy and the head of the Gulf for a distance of over fifty miles, and has a width varying from a few miles at the north to over twenty miles at its center. This flat is covered with shallow water at times when the Colorado River is in flood concurrently with spring tides in the Gulf. At the time of our visit the surface had been dry for several months and was coarsely broken by conchoidal fractures. The landward edges of the flat have a very thin stand of small mesquites at the northern end, many of which have been killed by the continued saturation of the substratum which is so fatal to this tree. The principal part of the flat is wholly devoid of vegetation. At the southern end of the Cucopa

Mountains, and among the smaller volcanic ranges immediately south of them, the customary development of bajadas has been prevented by the removal of outwash material by tidal action or its distribution over the level surface of the mud flat.

The slopes of the Cucopas facing the east are more nearly devoid of vegetation than any hills or mountains that the writer has seen in the southwestern deserts, not excepting those in the central part of the Mojave Desert. On several of the lower slopes that were examined there were no perennials and it was impossible to find traces of plants that might have grown there during rainy periods. It is very likely, however, that the vigorous winds which visit this region may have removed all evidence of herbaceous ephemerals, as there is always enough sand in motion near the ground in a high wind to cut the small dry stems. Other slopes that were visited bore a few small individuals of the barrel cactus *Ferocactus acanthodes* (*Echinocactus cylindraceus*). Near the bases of other slopes were a few individuals of *Covillea tridentata* and *Franseria dumosa*. On one hill there persisted a few tufts of a grass, apparently *Heteropogon contortus*. It is doubtful if there are any places in the western hemisphere where the landscape is more completely devoid of plant life than it is throughout the 30 or 40 miles of our journey in which the tidal flat formed the foreground and the barren hills rose abruptly from its inner edge.

The tidal flat was traversed to within about fifteen miles of its southern end, when both the Cucopa Mountains and the Sierra Pinta had been left behind. South of the latter range the nearest mountains are from five to twenty miles inland, and their bajadas drain down to the inner edge of the tidal flat. Here the alluvial soil of the flat receives an admixture of sand and infrequent irrigation with fresh water, and there is consequently a narrow zone of halophytic vegetation, chiefly *Frankenia Palmeri*, with occasional groups of *Spirostachys occidentalis*.

The bajadas south of the Sierra Pinta are covered with a relatively heavy stand of perennial vegetation, there being approximately from 40 to 60 individuals to the acre. The few species seen here are all common in similar situations throughout western Arizona and Sonora, including *Prosopis glandulosa*, *Olneya tesota*, *Covillea tridentata*, *Parkinsonia Torreyana* (*Cer-*

cidium), and *Franseria dumosa*. The cacti are conspicuously infrequent, being represented only by widely separated individuals of *Ferocactus acanthodes* and *Opuntia echinocarpa*. The surface of the bajada is like that in adjacent regions with very low rainfall, with a close network of small shallow drainageways and with no large ones.

South of the region just described it is necessary to traverse nearly twenty miles of light sand, which stretches from the mountains to the Gulf at this place. In this area, *Parkinsonia* and *Olneya* are absent and *Prosopis* is relatively infrequent, the dominant perennials being *Covillea*, *Acacia paucispina* and *Franseria dumosa*. All of the larger bushes in this wind-swept area have accumulated hummocks of sand, and groups of small dunes from six to twelve feet in height are common, always fairly well stabilized by an open cover of *Acacia* or *Covillea*.

The remainder of the journey to San Felipe Bay was across the bajadas of hills which rise from five to fifteen miles from the coast of the Gulf. On some of them there is a hard surface covered with desert pavement of small stones, on others a great deal of wind-blown sand, and on the greater part of them a soil which appears to be a loam with considerable coarse sand or fine gravel, which, however, is of very much finer texture than the surface material would indicate. Low and open stands of *Covillea*, with a few individuals of *Franseria* and *Acacia*, form the prevailing vegetation of this region. In many spots the number of plant individuals is less than twenty per acre. Under low bushes it is possible to find loose wind-blown fragments of herbaceous plants, which had been blowing about for eight months, or some of them possibly for twenty months. In this material it was possible to recognize species of *Cryptanthe*, *Amsinckia*, *Chorizanthe*, *Gilia* and *Plantago*.

Although the bajadas in general are without streamways, other than very shallow ones less than two or three feet in width, there are some places in which the configuration of the surface concentrates the very infrequent run-off into streamways from 15 to 75 feet in width. Along these streamways and in them are the heaviest stands of trees, with the largest individuals. *Prosopis*, *Olneya*, *Parkinsonia Torreyana* and *Parosela spinosa* here reach heights of 20 to 25 feet. The latter is one of the most striking trees of the Colorado and Gulf deserts. It is

without leaves in the dry seasons, is very richly branched, and its stems and twigs have a bluish gray color which almost masks the green and gives to the tree its popular name of "smoke tree." When it is in bloom, covered with a profusion of magenta flowers, it is one of the most unforgettable sights of the desert.

On reaching San Felipe Bay, camp was made near the well of slightly brackish water which affords the only supply in this region. The well is at the northern end of a narrow valley, with extremely fine alluvial soil, lying just back of the crest of the beach. The valley is covered with a sod of *Distichlis spicata*,

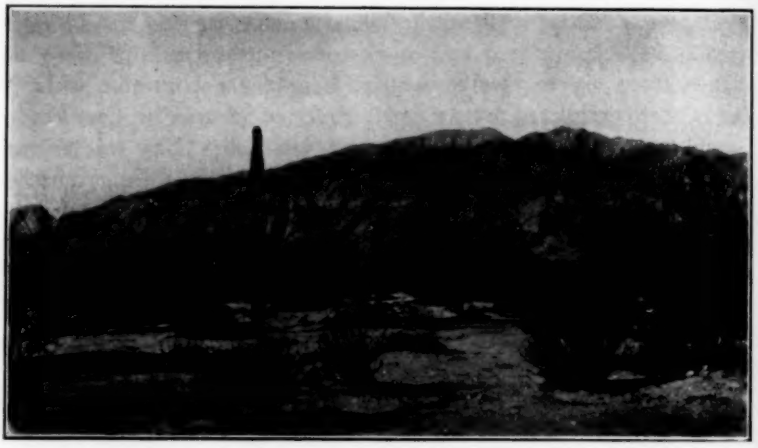

FIG. 2. Upper bajada west of San Felipe Bay. The cactus is *Pachycereus Pringlei;* to its left, *Elaphrium microphyllum;* to its right, *Elaphrium Macdougalii* and *Parkinsonia microphylla;* in the foreground, *Encelia farinosa.*

and has a few mesquite trees, which appear to be *Prosopis velutina*, rather than *P. glandulosa*, which is the common tree of the region. The northern limit of San Felipe Bay is formed by a short range of hills, and the southern boundary by lower hills, from which an extensive area of dunes and sandy soil extends inland to the mountains, marking the southern limit of progress with wheeled vehicles.

Directly west of San Felipe Bay the nearest mountains rise at a distance of about eight miles. The bajadas were explored on foot, and were found to bear a progressively heavier stand of vegetation as the mountains were approached. The commonest

forms are *Covillea*, *Acacia*, *Parkinsonia*, *Fouquiera*, *Encelia* and *Franseria*. Less frequent are *Olneya*, *Simmondsia* and a large *Krameria*.

Fouquiera here reaches the greatest size that has been observed anywhere in its range, being from 18 to 26 feet in height, sometimes with over one hundred branches, and commonly much more richly branched than at the northern edge of its range. A frequent tree here and for some twenty miles to the north is *Elaphrium microphyllum*, growing with the less frequent *E. Macdougalii*. This is the copal tree, also found in Sonora, the northernmost of the trees with greatly thickened and rapidly tapering trunk. The only other perennials not found in California are the columnar cereus, *Pachycereus Pringlei*, which is very infrequent here, and the *mochi*, *Lophocereus Schottii*, which is also infrequent. The only other cacti noted on the upper bajadas were *Opuntia Bigelovii*, *O. fulgida*, *O. ramosissima*, and *Ferocactus acanthodes*. All of these species are very infrequent. The lower slopes of the mountains west and southwest of San Felipe were very similar in their barrenness to those that have been described for the Cucopa Mountains.

The upper bajadas that have just been described were more thickly covered with plants than any of the other localities observed in the relatively short distance over which the coast was examined. The vegetation of these thickest stands is still very open and also very much poorer in species than similar topographic sites in Arizona or the interior of Sonora. The absence of the sahuaro, *Carnegiea gigantea*, and the presence of the copal tree give the landscape a very different aspect here. The slopes of the mountains form an even stronger contrast to those of regions with as much as ten inches of annual rainfall.

The vegetative activities of desert plants differ chiefly from those of moister regions in being intermittent. After heavy rains the desert plants grow, form leaves, bloom, and set seed with remarkable rapidity, and such seeds as are in the ground germinate and grow with equal rapidity. During a large part of the year, however, these plants are inactive and merely existing, with transpiration and respiration cut down to the lowest minimum. The different sections of the southwestern desert differ chiefly in the frequency and length of the periods in which the plants are quiescent. It is obvious that life and

growth, reproduction and migratory movements are more difficult in proportion as the quiescent periods are longer. The region between Imperial Valley and San Felipe Bay will always be one of great interest because its vegetation is the resultant of the highly intermittent activity of its plants through many centuries of deficient and irregular rainfall.

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Toxicity and antagonism in salt solutions as indicated by growth of wheat roots[1]

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(WITH FIVE TEXT FIGURES)

A simple method of studying root elongation in very young seedlings has been described in a previous paper (Trelease and Trelease, 1925). It was found that reliable solution-culture results may be secured if attention is confined to the first few days of seed germination and that by means of such tests physiological balance may be demonstrated in a quantitative manner. It is the purpose of this paper to present results which indicate that the same method may also be used in studying toxicity of single-salt solutions as well as antagonistic effects in mixed solutions.

It has long been known that a culture solution containing a single salt is usually toxic to plants, and that the toxicity of such a solution may in many cases be diminished by the addition of another salt, which would also be toxic in simple solution. This phenomenon of antagonism is of such fundamental importance in physiology that it has, of course, received much attention in the literature. Reference may be made here to the valuable discussions of the literature given by Stiles and Jörgensen (1914) and by Stiles (1923) as well as to a summary of Osterhout's important contributions to our knowledge of antagonism for plant tissues (Osterhout, 1922).

Much less is known of the causes of antagonism than of its effects. Osterhout (1922), who has developed an elaborate hypothesis to explain antagonism, supposes that the antagonistic salts combine with some constituent of the protoplasm (at the external surface of the cell or at internal surfaces) to form new compounds. As a result of the antagonistic action, the salts in a balanced solution penetrate living cells much more slowly than do salts in an unbalanced solution, and the slow penetration of antagonistic substances has no unfavorable influence on the life processes so long as the substances within the cell remain properly balanced.

[1] Contributions from the Department of Botany of Columbia University, no. 342.

It is probable that the causes of antagonism must be sought by determining the laws governing the absorption of salts, or ions, and by determining the nature and controlling conditions of the chemical reactions produced in the cell walls and at the surface and in the interior of the protoplasm of the cells. Nevertheless, a complete explanation of the phenomena will require much more information than we now possess regarding the effects of antagonism on growth and the processes which accompany it.

Many of the results reported in the literature of salt antagonism have been based on experiments with a very small number of plants. Although such tests illustrate antagonistic effects qualitatively, the quantitative significance of the data has in many cases been obscured, probably by the high degree of variability of the plants as well as by the complexity of the other influential conditions.

The present work was undertaken with the aim of determining whether root elongation of very young seedlings might be used for studies of antagonistic effects. For this purpose, a study was made of the rate of elongation of wheat roots immersed in solutions containing pairs of the salts, potassium nitrate (KNO_3), calcium nitrate ($Ca(NO_3)_2$), and magnesium nitrate ($Mg(NO_3)_2$), and in simple solutions of each of these salts. Every two-salt solution had a total concentration of 0.06 gram-molecule per liter, but in the various solutions of each series the volume-molecular proportions of the constituent salts were varied in a systematic manner. Since the various two-salt solutions were alike in molecular concentration, they differed from one another in osmotic concentration; values for the latter ranged from about 3 to about 4 atmospheres. The tests with single-salt solutions included a rather wide range of concentrations. A comparison was made of growth rates in the experimental solutions and in a standard three-salt solution, and the retardation of growth in the experimental solutions was used as the criterion of their toxicity.

These experiments were begun at the University of Louisville, and continued at Columbia University. It is a pleasure to acknowledge indebtedness to Professor Burton E. Livingston, of the Johns Hopkins University, for valuable suggestions in the preparation of this paper.

METHODS AND RESULTS

The culture methods were essentially the same as described in a previous paper (Trelease and Trelease, 1925). Seeds of a pure-line spring wheat (Marquis, Saskatchewan, no. 70, supplied by the University of Saskatchewan, through the kindness of Professor Manley Champlin) were soaked for three hours in tap water and then sprouted on wet blotting paper in a moist chamber. Each culture vessel consisted of a glass tumbler (capacity, 275 cc.) having a piece of paraffined bobbinet stretched over the top and fastened by a ligature of paraffined linen thread. The tumbler was placed in a 600-cc. beaker (Griffin low form), and both the tumbler and the space around it were filled with solution, the level of the latter being even with the top of the tumbler.

When the first root of each seedling was about 6 mm. long, the seedlings were placed upon the netting at the surface of the solution, so that every root dipped into the solution while the seed was exposed to the air. Duplicate cultures, each of 25 seedlings, were grown. The cultures were kept in darkness, and during the first two days each was covered with a watch glass. The duration of the test was the time required for the roots in a standard or control solution to elongate about 84 mm. (from 6 mm. to 90). This standard solution contained 0.02 M KH_2PO_4, 0.02 M $Ca(NO_3)_2$, and 0.02 M $MgSO_4$, and allowed relatively rapid growth of roots. At the end of the test the length of the longest root of each seedling was recorded. For each culture, the mean initial root length (about 6 mm.) was subtracted from the mean final root length, and the value for elongation thus obtained was expressed as a percentage of the average elongation for the standard solution. Thus, each value for elongation represents an average growth rate during a time-period defined by the average growth rate in a standard solution. The results of the various tests are summarized in TABLES 1–4, and they are shown graphically in FIGS. 1–5.

Attention should be called to the fact that these data do not show how the growth rate may have changed for successive time intervals within the experiment period. Nor do they permit comparisons to be made between the time periods required for the roots in the various solutions to make equal amounts of growth (Osterhout, 1922). Further studies are needed if information is to be secured concerning these features of the growth phenomena.

TABLE 1

*Growth of wheat roots in salt solutions**

CONCENTRATION		KNO_3			$Ca(NO_3)_2$					$Mg(NO_3)_2$		
Percentage of 0.06 M	M†	A	B	Ave.	A	B	C	D	Ave.	A	B	Ave.
0	0	—	—	82‡	—	—	—	—	82‡	—	—	82‡
1	.0006	—	—	—	—	—	—	—	—	21	19	20
2	.0012	—	—	—	52	56	—	—	54	15	14	15
4	.0024	—	—	—	38	44	—	—	41	10	11	11
10	.0060	80	73	77	28	30	33	31	31	7	9	8
20	.0120	54	59	57	29	30	31	29	30	6	9	8
30	.0180	34	36	35	28	30	35	31	31	6	6	6
40	.0240	30	25	28	37	37	40	34	37	3	4	4
50	.0300	23	22	23	38	41	38	41	40	4	5	5
60	.0360	21	19	20	—	—	38	41	40	3	4	4
70	.0420	15	16	16	39	43	39	42	41	3	2	3
80	.0480	14	13	14	—	—	41	43	42	3	3	3
90	.0540	14	11	13	37	38	40	40	39	3	1	2
100	.0600	7	10	9	36	37	35	37	36	1	1	1
200	.1200	1	1	1	19	22	—	—	21	—	—	—
300	.1800	0	0	0	—	—	—	—	—	—	—	—
400	.2400	0	0	0	0	1	—	—	1	—	—	—
600	.3600	—	—	—	0	0	—	—	0	—	—	—

* Duration of experiment the time required for roots in standard solution to elongate about 84 mm. (from 6 mm. to 90 mm.). Root growth expressed as percentage of elongation for standard solution containing 0.02 M KH_2PO_4, 0.02 M $Ca(NO_3)_2$, 0.02 M $MgSO_4$.

† M denotes the volume-molecular concentration, or the number of gram molecules contained in each liter of solution.

‡ The mean (82) for distilled water is based on 14 cultures, as follows: 78, 79, 86, 82, 82, 79, 86, 84, 85, 80, 83, 82, 78, 80.

In the various series the temperature ranged from about 18° to 23° C., the mean temperature usually being about 19° C. At this temperature the roots in the standard solution required about 90 hours to elongate 84 mm.

TABLE 2

*Growth of wheat roots in solutions of potassium nitrate and calcium nitrate, the total concentration of each solution being 0.06 M**

VOLUME-MOLECULAR PROPORTIONS†		ROOT GROWTH			GROWTH IN TWO-SALT SOLUTION MINUS GROWTH IN	GROWTH IN TWO-SALT SOLUTION MINUS GROWTH IN
KNO_3	$Ca(NO_3)_2$	A	B	Ave.	KNO_3‡	$Ca(NO_3)_2$‡
0	100	—	—	36	—	—
10	90	71	69	70	− 7	+31
20	80	76	67	72	+15	+30
30	70	79	76	78	+43	+37
40	60	83	82	83	+55	+43
50	50	82	84	83	+60	+43
60	40	90	85	88	+68	+51
70	30	87	80	84	+68	+53
80	20	83	86	85	+71	+55
90	10	80	80	80	+67	+49
100	0	—	—	9	—	—

* Duration of experiment the time required for roots in standard solution to elongate about 84 mm. (from 6 mm. to 90 mm.). Root growth expressed as percentage of elongation for standard solution containing 0.02 M KH_2PO_4, 0.02 M $Ca(NO_3)_2$, 0.02 M $MgSO_4$.

† Expressed as percentages of 0.06 M.

‡ Concentration the same as that in which the salt exists in the mixed solution.

‡ The mean (82) for distilled water is based on 14 cultures, as follows: 78, 79, 86, 82, 82, 79, 86, 84, 85, 80, 83, 82, 78, 80.

DISCUSSION OF RESULTS

Toxicity of single-salt solutions. The graphs of FIG. 1 show the relations between growth rates and volume-molecular concentrations of single-salt solutions. It will be observed that every single-salt solution allows less rapid growth than occurs in distilled water or in the standard solution (the latter being a physiologically fairly well balanced solution). The present results thus agree with what generally has been found true for single-salt solutions. For successively higher concentrations, the growth rates decrease rapidly at first and then more and more slowly. While the curvature of the graphs for KNO_3 and for

TABLE 3

*Growth of wheat roots in solutions of calcium nitrate and magnesium nitrate, the total concentration of each solution being 0.06 M**

VOLUME-MOLECULAR PROPORTIONS†		ROOT GROWTH			GROWTH IN TWO-SALT SOLUTIONS MINUS GROWTH IN $Ca(NO_3)_2$‡	GROWTH IN TWO-SALT SOLUTION MINUS GROWTH IN $Mg(NO_3)_2$‡
$Ca(NO_3)_2$	$Mg(NO_3)_2$	A	B	Ave.		
0	100	—	—	1	—	—
10	90	33	33	33	+ 2	+31
20	80	62	61	62	+32	+59
30	70	69	68	69	+38	+66
40	60	70	71	71	+34	+67
50	50	70	69	70	+30	+65
60	40	68	65	67	+27	+63
70	30	67	63	65	+24	+59
80	20	65	63	64	+22	+56
90	10	57	56	57	+18	+49
100	0	—	—	36	—	—

* Duration of experiment the time required for roots in standard solution to elongate about 84 mm. (from 6 mm. to 90 mm.). Root growth expressed as percentage of elongation for standard solution containing 0.02 M KH_2PO_4, 0.02 M $Ca(NO_3)_2$, and 0.02 M $MgSO_4$.

† Expressed as percentages of 0.06 M.

‡ Concentration the same as that in which the salt exists in the mixed solution.

$Mg(NO_3)_2$ is of the common type, that of the graph for $Ca(NO_3)_2$ is exceptional, since this graph at first falls, then rises, and finally falls again.

The relative growth-retarding effects of the three salts are in general agreement with most of the published data. Every tested concentration of $Mg(NO_3)_2$ retarded growth much more than did the same concentration of KNO_3 or of $Ca(NO_3)_2$. Even the lowest tested concentration of $Mg(NO_3)_2$, 0.0006 M, had a marked retarding effect. It is interesting to note that at low concentrations KNO_3 retarded growth less than $Ca(NO_3)_2$, while at high concentrations the reverse was true.

Stimulating effects on growth, such as have been observed by Jensen (1907), Brenchley (1914), and other workers, are not evident from the present results. The growth of the roots in distilled water was more rapid than in any of the single-salt solutions.

It will be seen from FIG. 1 that the concentrations that

prevent any growth during the experiment period are about 0.060 M for $Mg(NO_3)_2$, 0.120 M for KNO_3, and 0.240 M for $Ca(NO_3)_2$. But it may not be possible to determine such concentrations with any high degree of accuracy, since each of the graphs tends to make a very small angle with the base line.

TABLE 4

*Growth of wheat roots in solutions of potassium nitrate and magnesium nitrate, the total concentration of each solution being 0.06 M**

VOLUME-MOLECULAR PROPORTIONS†		ROOT GROWTH			GROWTH IN TWO-SALT SOLUTION MINUS GROWTH IN	GROWTH IN TWO-SALT SOLUTION MINUS GROWTH IN
KNO_3	$Mg(NO_3)_2$	A	B	Ave.	KNO_3‡	$Mg(NO_3)_2$‡
0	100	—	—	1	—	—
10	90	5	4	5	−72	+ 3
20	80	5	6	6	−51	+ 3
30	70	9	9	9	−26	+ 6
40	60	9	8	9	−19	+ 5
50	50	11	13	12	−11	+ 7
60	40	14	14	14	− 6	+10
70	30	17	19	18	+ 2	+12
80	20	26	29	28	+14	+20
90	10	32	36	34	+21	+26
100	0	—	—	9	—	—

* Duration of experiment the time required for roots in standard solution to elongate about 84 mm. (from 6 mm. to 90 mm.). Root growth expressed as percentage of elongation for standard solution containing 0.02 M KH_2PO_4, 0.02 M $Ca(NO_3)_2$, 0.02 M $MgSO_4$.

† Expressed as percentages of 0.06 M.

‡ Concentration the same as that in which the salt exists in the mixed solution.

The present results do not, of course, allow accurate inferences to be drawn regarding the limits of endurance of these wheat plants to the salts employed. Special studies of this phase of the problem have been made by Harter (1905) and Jensen (1907).

That the comparative growth rates in different salt solutions may depend upon the duration of the test has been emphasized by Magowan (1908), who pointed out that after six days wheat plants in NaCl and KCl solutions had made more growth than those in $CaCl_2$ solutions, but after twenty-five days the plants in $CaCl_2$ solutions were in advance of the others. It is clear therefore that comparisons cannot be made between experi-

ments of different durations until special tests have been made of the relations of the time-period, or of the developmental stage of the plants, to the toxic action of salt solutions.

Certain rather striking differences in the appearance of the roots were noticed. Roots that had grown in concentrations of $Ca(NO_3)_2$ lower than 0.03 M were covered with a heavy mat of long root hairs, this development of hairs being most conspicuous in the lowest concentrations and nearly absent in concentrations above 0.048 M. This action of calcium salts has been observed by a number of workers; Magowan (1908) refers to a similar

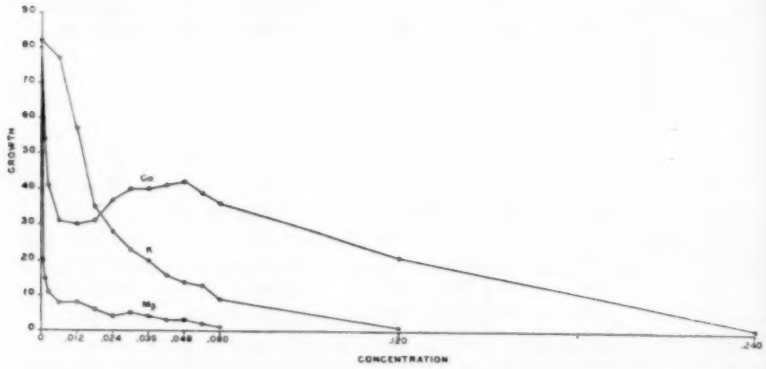

FIG. 1. Growth of wheat roots in single-salt solutions of nitrates of calcium (Ca), potassium (K), and magnesium (Mg).

Ordinates represent root growth, expressed as percentages of elongation for standard solution. Abscissas represent volume-molecular concentrations.

effect of $CaCl_2$ solutions, favoring the development of root hairs. The roots appeared more slender in higher concentrations. In the highest concentrations (0.24 and 0.36 M) of $Ca(NO_3)_2$, the roots were white and the same in appearance as when placed in the solutions. Roots that had grown in the higher concentrations of KNO_3 were translucent, swollen, soft and easily broken. The solution in which they had grown was opalescent. In the higher concentrations of $Mg(NO_3)_2$, five roots usually developed about equally, whereas in concentrated solutions of the other salts only one or three roots usually developed.

Toxicity of distilled water. Growth in distilled water was found to be more rapid than in any single-salt solution tested, and it was also more rapid than in any mixed solution containing

$Ca(NO_3)_2$ and $Mg(NO_3)_2$, or KNO_3 and $Mg(NO_3)_2$. But it was slightly less rapid than in many mixed solutions containing KNO_3 and $Ca(NO_3)_2$, and about 18 per cent less rapid than in the standard solution, containing KH_2PO_4, $Ca(NO_3)_2$, and $MgSO_4$. These facts are evident from the data of TABLES 1–4, and FIGS.

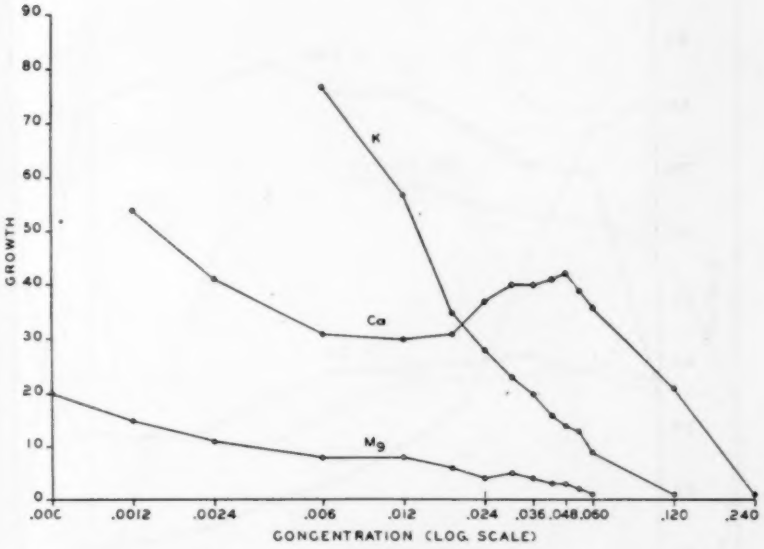

FIG. 2. Growth of wheat roots in single-salt solutions of nitrates of calcium (Ca), potassium (K), and magnesium (Mg).

Ordinates represent root growth, expressed as percentages of elongation for standard solution. Abscissas represent logarithms of volume-molecular concentrations.

1, 3, 4, and 5. The water used in the present tests was obtained from a Barnstead still. Some comparative tests indicated no significant difference between seedlings grown in this water and those grown in water redistilled from Pyrex flasks (with cotton plugs in place of cork or rubber stoppers). It is probable, therefore, that the results obtained with the various solutions of the present study are not very different from those that would have been secured if other precautions had been taken in the preparation of the distilled water used. However, on theoretical grounds, at least, water redistilled from glass (True, 1914;

Hibbard, 1915) or from quartz (Scarth, 1924) would be preferable in experiments of this kind.

In the present tests, the relatively less rapid growth in distilled water than in the standard solution and in certain two-

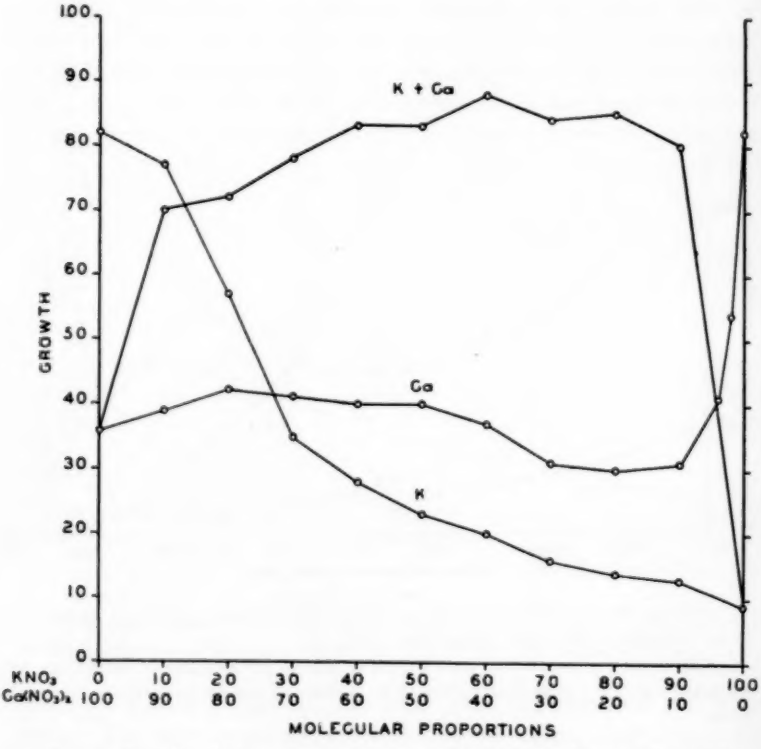

FIG. 3. Growth of wheat roots in two-salt solutions of nitrates of potassium and calcium (K + Ca), and in single-salt solutions of nitrates of potassium (K) and calcium (Ca).

Ordinates represent root growth, expressed as percentages of elongation for standard solution. Abscissas represent concentrations, expressed as percentages of 0.06 gram-molecule per liter.

salt solutions of KNO_3 and $Ca(NO_3)_2$ may perhaps be attributed to one or more of the following conditions: (1) the presence of growth-retarding substances in the distilled water, which might be antagonized by the solutes present in the standard solution, or by KNO_3 plus $Ca(NO_3)_2$, but not by $Ca(NO_3)_2$, KNO_3, or

$Mg(NO_3)_2$ alone—in the concentrations tested; (2) injurious action of distilled water due to complex effects upon permeability, such as have been suggested by True (1914); (3) so-called "nutritive effects" of the two-salt and three-salt solutions. Further study of this difficult subject is needed.

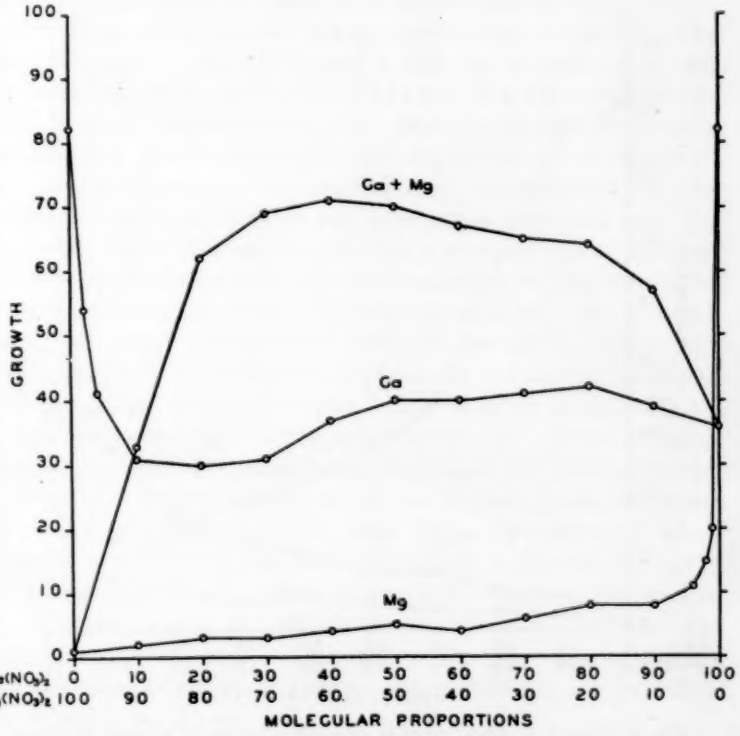

FIG. 4. Growth of wheat roots in two-salt solutions of nitrates of calcium and magnesium (Ca + Mg), and in single-salt solutions of nitrates of calcium (Ca) and magnesium (Mg).

Ordinates represent root growth, expressed as percentages of elongation for standard solution. Abscissas represent concentrations, expressed as percentages of 0.06 gram-molecule per liter.

Peculiar rise of $Ca(NO_3)_2$ graph. The peculiar rise in the $Ca(NO_3)_2$ graph deserves special attention. That this rise is significant is supported by the fact that a repetition of the test (as shown by data of TABLE 1), with new solutions, gave almost exactly the same results as the first test. It is possible that this

rise in the graph may have been due to a difference in the type of response of the roots. As already mentioned, it was noted that in very low concentrations of this salt, the roots were covered with a heavy mat of long hairs, while at higher concentrations

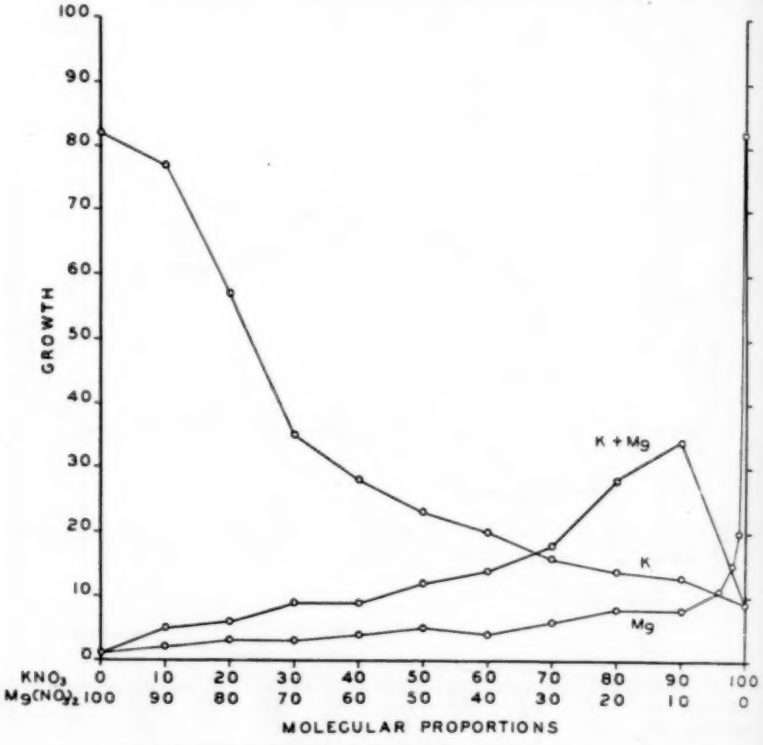

Fig. 5. Growth of wheat roots in two-salt solutions of nitrates of potassium and magnesium (K + Mg), and in single-salt solutions of nitrates of potassium (K) and magnesium (Mg).

Ordinates represent root growth, expressed as percentages of elongation for standard solution. Abscissas represent concentrations, expressed as percentages of 0.06 gram-molecule per liter.

the roots appeared more slender and hairs were much less abundant. It is possible that increase in dry weight, increase in volume, or some other criterion of growth or development, might show a simple curve such as that obtained for root growth with KNO_3 and $Mg(NO_3)_2$. Another possible suggestion is that the fall in the graph at very low concentrations may have been

related to progressive alteration in the culture solution brought about by the plants during the period of the test. It has been noted that the plants were in many cases more variable in very dilute solutions than in more concentrated solutions. Experiments with continuously renewed solutions (Trelease and Livingston, 1922) might be used to test this possibility.

Dissimilar effects of dilution of equally toxic solutions. The data of TABLE 1, plotted in FIG. 1 with an ordinary scale for concentrations, have been replotted in FIG. 2, using a logarithmic scale. For any ordinate (or growth rate) the horizontal distance between two graphs represents the logarithm of the ratio of the two abscissas (or concentrations). Accordingly, if the horizontal distances between any two graphs were the same for all growth rates, this would indicate a constant ratio between the concentrations of equally toxic solutions of the two salts (using growth rates as the criterion of toxicity); or, in other words, for equal growth rates the concentration of one salt would always be a constant multiple of the concentration of the other salt. The two graphs might then be made to coincide by moving one to the right or the other to the left. If this relation existed, any pair of equally toxic single-salt solutions might be selected, and these solutions would not become unequally toxic when both were diluted to the same degree (for example, when the volume of both were doubled, tripled, etc.). Osterhout (1915) states that in most cases which have come under his observation two solutions which are equally toxic remain so (at least approximately) when both are diluted to the same degree, but he also discusses other cases that might possibly occur in which this relation would not hold.

An examination of FIG. 2 shows clearly that the horizontal distance between any pair of graphs is generally different for various growth rates. No simple constant relation exists between equally toxic concentrations of the salts in question. For these tests it is therefore evident that any pair of solutions having equal growth-retarding effects would generally have unequal growth-retarding effects when diluted to the same degree.

Clear demonstration of antagonism. The diagrams of FIGS. 3–5, present the results of the tests with mixed solutions, containing pairs of the salts, KNO_3, $Ca(NO_3)_2$, and $Mg(NO_3)_2$. Besides the graph for the growth rate in the solutions containing

the two salts, each diagram also shows the graphs for the growth rate in the simple solutions of each salt in the concentrations in which it existed in the mixed solutions.

Whether or not antagonism exists in a mixed solution of two salts (each of which would retard growth in simple solution) may in most cases be determined if we know (1) the growth rate in the mixed solution, (2) the growth rate in a simple solution of the first salt in the concentration in which it exists in the mixed solution, and (3) the growth rate in a simple solution of the second salt in the concentration in which it exists in the mixed solution. It is clear that antagonism may be considered to exist if the growth rate in the mixture is more rapid than in the simple solution having the greater growth-retarding effect.[2] This is the criterion of antagonism that generally has been employed by investigators, and it will be used in the present paper. Data for the necessary comparisons are available in this study, since growth data are shown, in the tables and in the graphs, for the simple solutions as well as for the mixtures.

According to the criterion here used, antagonism may be considered to exist wherever the graph representing the growth in the mixed solutions lies above the lower of the two graphs for the single-salt solutions. It will be observed that the graphs give a clear demonstration of antagonism for all tested two-salt solutions. Antagonism is especially pronounced for mixtures of KNO_3 plus $Ca(NO_3)_2$, and $Ca(NO_3)_2$ plus $Mg(NO_3)_2$, while it is much less marked for mixtures of KNO_3 plus $Mg(NO_3)_2$. This result is in agreement with what has generally been reported in the literature (for example, McCool, 1913).

In this connection, it is of interest to refer to methods of estimating in a quantitative manner the antagonistic effects of a mixed salt solution. As Osterhout (1914a, 1915, 1918) has shown, an accurate quantitative expression of antagonistic effects may be obtained if it is possible to estimate the total growth-retarding effect that the mixed solution would have if neither salt influenced the growth-retarding effect of the other salt. This total growth-retarding effect, Osterhout has termed

[2] Antagonism may exist even if the growth rate in the mixed solution is less rapid than in the more toxic single-salt solution, but it cannot be demonstrated unless an accurate calculation can be made of the "additive effect" (Osterhout, 1915, 1918) of the mixed solution.

the "additive effect." Antagonism might then be expressed accurately as the difference between the additive effect and the *actual* growth-retarding effect of the mixed solution.

If the toxic effects of the salts were exactly alike—that is, if the salts affected the same processes in the same qualitative manner—the additive effect might then be the sum of the separate toxicities of the two salts, when these toxicities were expressed in proper terms. Osterhout has shown that such a summation of the toxicities might be obtained if the effect of one salt might be expressed in terms of the other salt. For example, this might be done if the quantitative effects of the two salts were so related that, for equal growth-retarding effects, the concentration of the first salt were always a constant multiple of the concentration of the second salt. Under these conditions, equally toxic solutions of the two salts would remain equally toxic when diluted to the same degree. Osterhout (1914a) has employed a convenient method that may be used in studying antagonism between two salts which are known to be related in this manner.

As pointed out in an earlier section of this paper, equally toxic solutions of the salts here employed would not remain equally toxic when diluted to the same degree, and no constant relation is evident which would make it possible to express accurately the effect of one salt in terms of another salt. Although approximate calculations of additive effect and antagonism might be made in such cases, the simpler criterion given above has been considered adequate for the purposes of the present paper.

Form of graphs for growth in mixtures. It will be seen that the curves for KNO_3 plus $Ca(NO_3)_2$ and for $Ca(NO_3)_2$ plus $Mg(NO_3)_2$ are round-topped, with no sharp optimum set of proportions. The shape of the curve for KNO_3 plus $Mg(NO_3)_2$, however, is different from that of the other two and indicates a rather sharply defined optimum for a mixture of 90 per cent KNO_3 plus 10 per cent $Mg(NO_3)_2$.

The relative degree of sensitiveness of the roots to differences in salt proportions may be illustrated by the range of salt proportions in each case which allows relatively rapid growth—for example, 85 per cent or more of the maximum growth rate. The following tabulation shows this range for each mixture:

From 25 per cent KNO_3 + 75 per cent $Ca(NO_3)_2$ *to* 91 per cent KNO_3 + 9 per cent $Ca(NO_3)_2$.

From 19 per cent $Ca(NO_3)_2$ + 81 per cent $Mg(NO_3)_2$ *to* 86 per cent $Ca(NO_3)_2$ + 14 per cent $Mg(NO_3)_2$.

From 81 per cent KNO_3 + 19 per cent $Mg(NO_3)_2$ *to* 92 per cent KNO_3 + 8 per cent $Mg(NO_3)_2$.

Thus 85 per cent or more of the maximum growth rate was secured with 66 per cent of the possible range of proportions of KNO_3 plus $Ca(NO_3)_2$, with 67 per cent of the range of proportions of $Ca(NO_3)_2$ plus $Mg(NO_3)_2$, but with only 11 per cent of the range of proportions of KNO_3 plus $Mg(NO_3)_2$.

Molecular ratios may be used similarly. For solutions giving 85 per cent or more of the maximum growth rate, the values of the ratio of KNO_3 to $Ca(NO_3)_2$ range from 0.33 to 10.1, those of the ratio of $Ca(NO_3)_2$ to $Mg(NO_3)_2$ range from 0.23 to 6.1, and those of the ratio of KNO_3 to $Mg(NO_3)_2$ range from 4.3 to 11.5.

The present data suggest that for a total molecular concentration of 0.06 M, the two-salt solutions which would allow most rapid growth might have approximately the following molecular proportions: (1) 60 per cent KNO_3 plus 40 per cent $Ca(NO_3)_2$, (2) 40 per cent $Ca(NO_3)_2$ plus 60 per cent $Mg(NO_3)_2$, (3) 90 per cent KNO_3 plus 10 per cent $Mg(NO_3)_2$. But careful tests with large numbers of wheat seedlings would be necessary to determine with any high degree of accuracy the exact proportions of the optimum solutions, for any given set of non-solution conditions.

The wide range of salt proportions (or molecular ratios) allowing approximately optimum growth is one of the outstanding features of the results here reported. Earlier investigations of two-salt solutions, where actual data have been given, have generally indicated much narrower limits for this range. For example, the results of Osterhout (1909) for concentrated solutions indicate sharply defined optimum salt proportions. The difference in question appears to be related to the total concentrations employed. For any pair of salts, the form of the growth curve may be expected to be greatly influenced by the total concentration of the solution. Thus, Osterhout (1914b) gives diagrams showing how the form of the growth curve for mixed solutions is altered with dilution of the latter. He states that with dilution the growth curve becomes flatter, and that at great

dilution it must tend to become a horizontal straight line. As the concentration is lowered, the growth-retarding effect diminishes and its inhibition is consequently less striking (Osterhout, 1908).

In each diagram the abscissa corresponding to the point of intersection of the graphs for the single-salt solutions indicates the mixed solution composed of equally toxic concentrations of the two constituent salts. These points are approximately as follows:

27 per cent KNO_3 + 73 per cent $Ca(NO_3)_2$,
99 per cent $Ca(NO_3)_2$ + 1 per cent $Mg(NO_3)_2$,
96 per cent KNO_3 + 4 per cent $Mg(NO_3)_2$.

Mixed solutions to the left of this point, in each case, are ones in which the first salt may be regarded as existing in the less toxic concentration, while mixed solutions to the right are ones in which the second salt may be considered as existing in the less toxic concentration.

It will be noted that for each pair of salts the graph representing the growth rate in the mixed solutions lies entirely above the lower of the two graphs for the single-salt solutions. Thus the growth in every two-salt solution is more rapid than in the corresponding simple solution of the constitutent salt existing in the more toxic concentration.

Moreover, for each pair of salts the graph representing the growth rate in the mixed solutions lies, for a considerable portion of its range, above the higher of the two graphs for the single-salt solutions. The following summary shows the range of salt proportions including every two-salt solution in which the growth is more rapid than in the corresponding simple solution of the constituent salt existing in the less toxic concentration:

From 13 per cent KNO_3 + 87 per cent $Ca(NO_3)_2$ *to* 96 per cent KNO_3 + 4 per cent $Ca(NO_3)_2$.

From 10 per cent $Ca(NO_3)_2$ + 90 per cent $Mg(NO_3)_2$ *to* 99 per cent $Ca(NO_3)_2$ + 1 per cent $Mg(NO_3)_2$.

From 68 per cent KNO_3 + 32 per cent $Mg(NO_3)_2$ *to* 98 per cent KNO_3 + 2 per cent $Mg(NO_3)_2$.

Thus 83 per cent of the possible total range of mixtures is included for the first mixture, 89 per cent for the second mixture, but only 30 per cent for the third mixture. Within these limits, antagonism is shown in a striking manner, and the salts are seen to be mutually antagonistic.

Toxicity of mixtures. It is interesting to compare the maxi-

mum growth rates for the three pairs of salts. Growth in the best solution containing KNO_3 plus $Ca(NO_3)_2$ was 88 per cent as rapid as in the three-salt solution (containing KH_2PO_4, $Ca(NO_3)_2$, and $MgSO_4$) used as the standard solution and was more rapid than in distilled water (the latter allowing a growth rate 82 per cent as rapid as in the standard solution). The best solution containing $Ca(NO_3)_2$ plus $Mg(NO_3)_2$ allowed almost as rapid growth (71 per cent of the rate for the standard solution), while the best solution containing KNO_3 plus $Mg(NO_3)_2$ permitted much less rapid growth (only 34 per cent of the rate for the standard solution). These general relations might be expected from the relative growth-retarding effects of the single-salt solutions, $Mg(NO_3)_2$ generally having a greater retarding effect than KNO_3, and the latter a greater retarding effect than $Ca(NO_3)_2$. Combinations of the two more toxic salts (KNO_3 and $Mg(NO_3)_2$) give greater growth retardation than combinations of the most toxic salt ($Mg(NO_3)_2$) with the least toxic salt ($Ca(NO_3)_2$), and the latter give greater retardation than combinations of the two less toxic salts (KNO_3 and $Ca(NO_3)_2$).

SUMMARY

A study was made of the rate of elongation of wheat roots immersed in simple solutions of potassium nitrate, calcium nitrate, and magnesium nitrate, and in solutions containing pairs of these salts. The single-salt solutions included a wide range of concentrations. Every two-salt solution had a total concentration of 0.06 gram-molecule per liter, but in the various solutions of each series the volume-molecular partial concentrations of the constituent salts were varied in a systematic manner.

The results of this study indicate that very young wheat seedlings can be used satisfactorily for demonstrating the growth-retarding effects of single-salt solutions and the antagonistic action of mixed solutions.

The relative degrees of toxicity of the three salts (as indicated by growth-retarding effect) were found to be in general agreement with most published data. For equal molecular concentrations, magnesium nitrate was much more toxic than either potassium nitrate or calcium nitrate. It was found that at low concentrations potassium nitrate was less toxic than calcium nitrate, while at higher concentrations the reverse was true.

By means of graphs in which a logarithmic scale is used for concentrations, it is shown that, for these salts and conditions, equally toxic simple solutions of different salts usually become unequally toxic when these solutions are diluted to the same degree.

Antagonism was found to be especially pronounced for mixed solutions of potassium nitrate and calcium nitrate, and of calcium nitrate and magnesium nitrate, but it was much less marked for mixed solutions of potassium nitrate and magnesium nitrate.

Some striking differences in appearance of roots grown in single-salt solutions are described, which indicate that each salt has specific toxic effects.

Methods of measuring antagonism in a mixed salt solution are briefly discussed, with special reference to the assumptions involved.

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On Lupinus fraxinetorum Greene

William A. Dayton

(with plate 5 and two text figures)

Lupinus fraxinetorum was published by the late Dr. Edward L. Greene in Leaflets, Vol. II, pp. 234–5, 1912, and is founded on Mr. Ralph Hopping's *no. 8*, Forest Service serial no. 3055, collected in 1911 in Fresno County, California, on the Sequoia National Forest. The type is in the U. S. National Herbarium, but part of the type material (the 'isotype,' to use Dr. Pennell's convenient term) is deposited in the herbarium of range plants in the Washington office of the Forest Service. This isotype is illustrated herewith in PLATE 5. Unfortunately the indument on the stem (and, to a lesser extent, on the leaflets) of conspicuous long, not dense, spreading, multicellular hairs, which is so conspicuous a feature of these specimens, is not brought out in the photograph. These hairs have the fulvous aspect that is often observed, for example, in much California herbarium material labeled *Lupinus leucophyllus*.

It is not for the present writer to comment concerning the the specific status of *Lupinus fraxinetorum;* its adequate diagnosis must be left to special students of this difficult genus, such as Professors Robinson and C. Piper Smith, Mr. Eggleston, and Dr. Rydberg. Suffice it for the nonce to state that the plant possesses 'an aspect,' and, while the accompanying illustrations (PLATE 5, and FIG. 1, b) fail to show, for example, the glabrity of the subrhomboid banner (an item not alluded to in Dr. Greene's original diagnosis of the species) yet PLATE 5 does indicate clearly the ample free stipules to which the author of the species refers.

The writer wishes to call attention to the fact that it was the intention of Dr. Greene to name this plant *Lupinus fraxineus* and that the specific name, *'fraxinetorum,'* which the latter published for the species was a slip-of-the-pen and a misnomer. PLATE 5 and FIG. 2 herewith both indicate plainly, in Dr. Greene's own handwriting, that *Lupinus fraxineus* was the name which he intended to bestow upon it. In 1912 Dr. Greene visited my office to notify me of his interest in Forest Service specimen no. 3055, which (as was his wont in such cases) he designated as

"New to me, hence new to Science!" He told me he had bestowed the name of *Lupinus fraxineus* on this new lupine, stating, in his characteristic fashion, that "Many botanists would dub such a plant '*Lupinus fresnoensis*,' a clear barbarism, which one familiar with the Spanish etymology of Fresno (California) would not perpetrate."

It was evident from the start that Dr. Greene regarded this plant not at all as one growing in ash woods as the specific

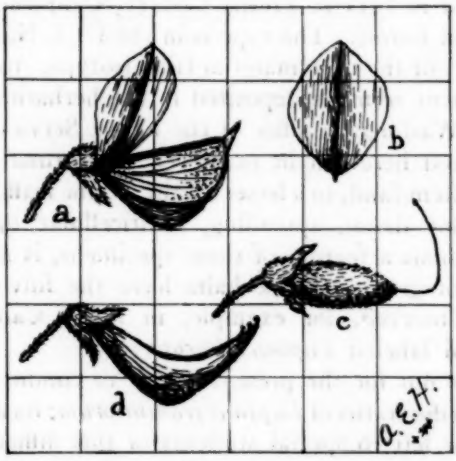


FIG. 1. Some floral aspects of *Lupinus fraxineus* Greene: (a) Flower; (b) Banner, or standard; (c) Immature pod, showing persistent, reflexed and geniculate style; (d) Keel, undetached from calyx.

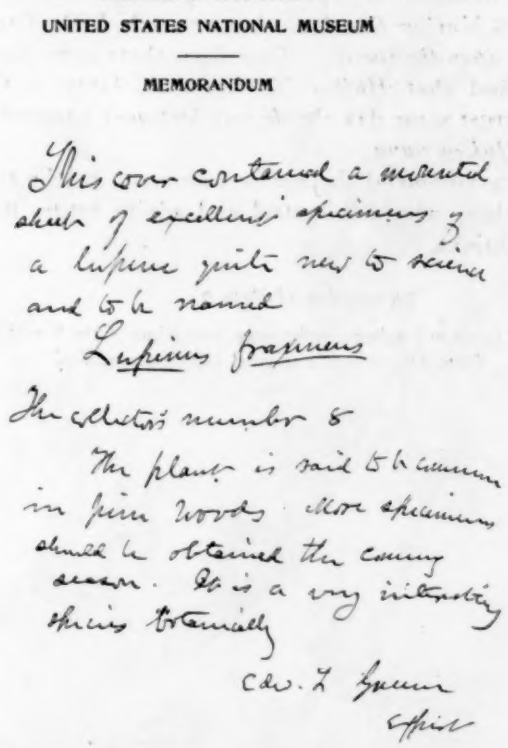
The background is of 9 centimeters square, the small squares 5 mm. square, all × 2.

name *fraxinetorum* would indicate,[1] but as being connected geographically with Fresno County, and he told me, with visible embarrassment after the specific name *fraxinetorum* appeared in print, that that was not the name he intended to publish. In fact, the concluding sentence of his original description clearly demonstrates that a mnemonic lapse resulted in the published name *fraxinetorum*.

The writer of this article maintains that *Lupinus fraxineus* Greene is the rightful name of this lupine, and that *L. fraxinetorum* is a usurper and can only technically be maintained. He

[1] Note in PLATE 5 that Mr. Hopping collected this plant in yellow pine timber.

would like to urge upon the nomenclatorial pundits of the botanical world the adoption of some ruling whereby names that are clearly slips-of-the-pen, misnomers unintended by their makers, should be suppressed in favor of the respective names



SMITHSONIAN INSTITUTION
UNITED STATES NATIONAL MUSEUM

MEMORANDUM

This cover contained a mounted sheet of excellent specimens of a lupine quite new to science and to be named
Lupinus fraxineus
The collector's number 8
The plant is said to be common in pine woods. More specimens should be obtained the coming season. It is a very interesting species botanically
Chas. L. Greene
Ephila

FIG. 2. The memorandum, in Dr. Greene's own hand, which he put in the folder of Forest Service specimen no. 3055, from which he had withdrawn the type material of his *Lupinus fraxineus*. Note especially the form of the specific name. The original memorandum is filed with the isotype in the range herbarium of the Forest Service, Washington, D. C.

wherewith those authors obviously intended to christen their plant children.

I have another analogous case of this sort just at present in mind. In his original description of *Hulsea nana* (Pacific Railroad Report, Vol. 6, Pt. 3, p. 76, 1857) Dr. Gray has this noteworthy sentence: "This is one of the most interesting plants

of Dr. Newberry's collection, and I have great pleasure in proposing that the species shall bear his name." Unless, indeed, one maintains the incredible thesis that the illustrious Asa Gray gave expression here to a most extraordinary bit of satire or sardonic humor, one cannot possibly conclude that *Hulsea nana* bears the name of its type collector, Dr. Newberry, or in any way honors him, *or that it is the name which Dr. Gray intended to confer upon the species*. Therefore, there is no doubt in the writer's mind that *Hulsea Newberryi* A. Gray is the *de veritate* (and I trust some day the *de jure factoque*) name of what is now called *Hulsea nana*.

I respectfully commend the above comments to the earnest meditation of those who will control and advise future nomenclatorial conventions.

Description of plate 5

The isotype of *Lupinus fraxineus* in the range herbarium of the Forest Service Washington, D. C. Note Dr. Greene's original identification slip.

DAYTON: ON LUPINUS FRAXINETORUM

Notes on Fabaceae—VII

PER AXEL RYDBERG

GEOPRUMNON Rydberg

The genus was described (Small, Fl. S. E. U. S. 615, 1332. 1903) from five species of *Astragalus*, of which *A. crassicarpus* Nuttall was regarded as the type. It corresponds to Gray's section SARCOCARPI and is characterized by the thick, fleshy, 2-celled pod, becoming spongy in age and tardily dehiscent, many-seeded. The genus is wholly North American and consists of the following species.

Pod glabrous, at least in age.
- Pod subglobose or broadly ellipsoid, abruptly mucronate at the apex.
  - Calyx strigose.
    - Pod subglobose, about as broad as long, 2–2.5 cm. long; corolla about 2 cm. long.
      - Corolla purple; leaflets oblong to linear ..... 1. *G. crassicarpum*
      - Corolla cream-colored with purple keel; leaflets oval or obovate ..... 2. *G. succulentum*
    - Pod broadly ellipsoid, 2.5–3 cm. long; corolla about 3 cm. long, white or ochroleucous ..... 3. *G. mexicanum*
  - Calyx densely woolly; corolla ochroleucous; pod subglobose ..... 4. *G. trichocalyx*
- Pod obliquely ovoid, acuminate; corolla ochroleucous; leaflets lance-oblong ..... 5. *G. pachycarpum*

Pod pubescent.
- Pod somewhat oblique but not curved, less than 2 cm. long, short-acuminate; stems with short ascending hairs ..... 6. *G. plattense*
- Pod arcuate, more than 2 cm. long, gradually acuminate; stem with long spreading hairs ..... 7. *G. tennesseense*

1. GEOPRUMNON CRASSICARPUM (Nutt.) Rydb. *Astragalus crassicarpus* was described by Nuttall in Frazer's Catalogue of 1813. The description is quite inadequate, consisting only of the following: "‡ Fruit about the size and form of *A. physodes*, but thick and succulent. Collected above the Platte River." [The sign ‡ stands for perennial.] There is, however, no uncertainty about the identity of the plant as it is the only species which grows in the region of Nuttall's travels along the Missouri River and which fits this description. *A. carnosus* Pursh was

described from specimens collected in "Upper Louisiana" by Bradbury, who accompanied Nuttall on the trip mentioned. Bradbury's specimens consisted of flowers of *Sophora sericea* and fruit of *A. crassicarpus*. Pursh also compares the fruit with that of *A. physodes*. The first complete description was that by Kerr in the Botanical Register, *plate 176*, under the name of *A. caryocarpus*. It was also illustrated on *plate 1324* of the same work under the name of *A. succulentus* Richards. See next species. The species grows on the prairies and plains from Manitoba to Missouri, Tennessee, Texas, New Mexico, Montana, and Saskatchewan.

2. GEOPRUMNON SUCCULENTUM (Richards.) Rydb. *Astragalus succulentus* Richardson was collected on Franklin's first journey. There is some doubt as to the identity of this species, as Richardson did not have mature fruit, but it cannot be the species illustrated under that name in the Botanical Register, *plate 1324*, for the plate illustrates a purple-flowered plant, evidently the same as *A. caryocarpus* Kerr (see above); while Richardson described his plant as having ochroleucous corolla with the keel purple. Thinking that the plate mentioned represented the original *A. succulentus* Richardson, I redescribed the present species under the name *A. prunifer*. It differs from *G. crassicarpum* besides in the color of the flower, in the lighter green foliage, the broader leaflets and the usually somewhat larger flowers and fruit. Webber in his Catalogue of the Flora of Nebraska mistook it for *A. mexicanus* A. DC., under which name it appeared in my treatment of the Flora of Nebraska. In fact it is more closely related to that species than is *A. trichocalyx* Nutt., to which Gray applied the name *A. mexicanus*. It is distributed from Saskatchewan and Alberta to Colorado.

3. GEOPRUMNON MEXICANUM (A. DC.) Rydb. *Astragalus Mexicanus* A. DC. was described from specimens collected in Texas by Berlandier. Torrey & Gray in their flora, page 693, referred this to *A. trichocalyx* Nutt., and Gray (Proc. Am. Acad. **6**: 193. 1863) formally adopted *A. mexicanus* for the latter. Botanists in general have followed their interpretation, but neither Berlandier's specimens nor A. de Candolle's plate warrant it; neither illustrates a plant with a woolly calyx. In Can-

dolle's diagnosis, the fruit is described as being glabrous, but the plate shows a few hairs. The fruit, as illustrated, differs from that of both *A. crassicarpus* and *A. trichocalyx* Nutt., in being larger and more elongate. A good illustration is given by Jones in his Revision of Astragalus under the name *A. crassicarpus pachycarpus*. *Berlandier 358* has a fruit 3 cm. long and 1.15 cm. in diameter, and perfectly glabrous. Heller's specimen from Kerrville has one 3.5 cm. long and 2 cm. thick. The flower resembles mostly that of *G. plattense* but is larger and with longer calyx-teeth. In *Lindheimer 597* the corolla is 28 mm. long. This number was rightly referred to *A. mexicanus* in *Plantae Lindheimerianae* by Dr. Gray, but later he has written on the label "*A. Plattensis* Nutt. wrongly referred in Pl. Lindh. to *A. mexicanus*." In *Plantae Wrightianae* he transferred this number to *A. plattensis*. His statement that the ovary is pubescent is so far correct that it is minutely puberulent. The fruit of *Berlandier 358* is, however, quite different from that of *G. plattense*, twice as long, at least 3 times as broad in the median plane, and not acuminate. The following specimens belong here.

TEXAS: *Berlandier 358; 273; Lindheimer 597, 200, 230,* in part; *Wright* in 1848; Kerr Co., *Bray 219; Heller,* in 1894; Bexar Co., *Ellen Schulz 298; 23.*—KANSAS: Cherokee Co., *Hitchcock 1015.*—? NEBRASKA: Hyannis, *Morris 518.* These specimens are doubtful, being in fruit and leaves mostly gone; but the large fruit indicates this species.

4. **Geoprumnon trichocalyx** (Nutt.) Rydb. *Astragalus trichocalyx* Nutt. T. & G. Fl. N. Am. **1:** 322. 1838. *Astragalus mexicanus* A. Gray, Pl. Wright **1:** 51, in part. 1852. *Geoprumnon mexicanum* Rydb.; Small. Fl. S. E. U. S. 616, 1332, in part. 1903. Outside of the confusion in nomenclature (in its being mistaken for *A. mexicanus*), this species has been well understood.

ILLINOIS: Bluffs, *Eggert,* in 1875; Joliet, *E. J. Hill,* in 1902.—MISSOURI: *Riehl 330;* St. Louis, *Halsted & Engelmann; Engelmann,* in 1832; *Geyer,* in 1842; *Eggert,* in 1875 and 1877; Jefferson Co., *Hasse,* in 1887; Montier, *Bush 1486, 6654;* Raynolds, *Eggert,* in 1887; Allenton *Letterman,* in 1912; St. Louis Co., *Glattfelder,* in 1894; Willard, *Blankinship,* in 1887.—OKLAHOMA: Vinita, *Carleton, 38,* in 1891.—LOUISIANA: *Hale.*—ARKANSAS:

Nuttall; Fayetteville, *Wells 29.*—TEXAS: *Wright* (in fruit); *Lindheimer 230,* in part; *E. Meyer,* in 1844; *Eggert,* in 1897.

5. GEOPRUMNON PACHYCARPUM (T. & G.) Rydb. *Astragalus pachycarpus* was described from fruiting specimens collected by Leavenworth. Dr. Gray regarded it as a depauperate form of *A. caryocarpus* (i. e. *G. crassicarpum*); but the fruit is that of *G. plattense,* though glabrous. The leaflets, however, are narrower and inclined to be acutish and the pubescence is more appressed. I have seen no specimens with mature fruit except the type. There are, however, flowering specimens and specimens in young fruit which have narrow leaflets. The former have the flowers of *G. plattense* rather than *G. crassicarpum.* The specimens with young fruit might belong to *G. crassicarpum,* but I am inclined to refer them here. If *A. pachycarpus* should be reduced, it should be to a variety of *G. plattense,* not to *G. crassicarpum,* as Jones has done. Some of the specimens cited by him (Contr. W. Bot. **8**: 17. 1898) evidently belong here, but the illustration of the pod in his Revision, evidently belongs to *G. mexicanum.* On the other hand one of the fruits (the glabrous one) intended to represent *A. plattensis,* looks more like that of the type of *A. pachycarpus.*

TEXAS: *Lindheimer 596; 745, 744;* San Filipe de Austin and San Patricio, *E. Meyer,* in 1844; Bexar County, *Jermy 17.*—ARKANSAS: *Leavenworth.*—? ARIZONA: *C. D. Marsh 14242* (U. S. Nat. Herb. *1117846*). This specimen was collected in fruit only and is doubtful. The pods being more abruptly contracted at the apex and the epicarp thinner.

6. GEOPRUMNON PLATTENSE (Nutt.) Rydb. This has ovoid, acuminate, strigose pods, and rather small ochroleucous or cream-colored corollas, only the keel tipped with purple. Its distribution extends from Indiana (?) to Minnesota and the Black Hills (South Dakota), south to Texas and Alabama.

7. GEOPRUMNON TENNESSEENSE (A. Gray) Rydb. This differs from the rest of the species in its long villous stem and pod and in the pod being lanceolate in outline.

TENNESSEE: Glades, *Gattinger,* in 1878, 1880 and 1881, also (Curtis' no.) *593;* Nashville, *Dr. Roane, Bicknell; Gattinger Hubbard; Lesquereux; Rutherford; Eggert,* in 1898.—ALABAMA: *Hatch,* in 1854.—ILLINOIS: Ottawa, *Bebb* in 1897 (This spe)

men has narrow leaflets and stipules); Ogle Co., *Bebb;* Morris, *Vasey*, in 1861; Marseilles, *Johnson*, in 1900.

HESPERASTRAGALUS Heller

The genus was established by Heller (Muhlenbergia **2:** 87. 1905) and based on Gray's section DIDYMOCARPI of Astragalus. Jones extended Gray's section so as to include also the REFLEXI. This disposition I am inclined to follow. *Astragalus Breweri*, however, included by Jones, does not belong here. Heller's diagnosis of the genus must therefore be somewhat modified.

Pod decidedly longer than broad, broadest below the middle and tapering at the apex. ..... 1. REFLEXI
Pod about as broad as long or broader, rounded and merely mucronate at the apex.
  Body of the pod fully 5 mm. long ..... 2. DIPHACI
  Body of the pod about 3.5 mm. long or less ..... 3. DIDYMOCARPI

1. REFLEXI

Annual; leaflets obovate, deeply retuse at the apex ..... 1. *H. reflexus*
Perennial with a creeping rootstock; leaflets linear-oblong ..... 2. *H. oxyrhynchus*

1. **Hesperastragalus reflexus** (T. & G). Rydb. *Astragalus reflexus* T. & G. Fl. N. Am. **1:** 334. 1838. In this species the ovules are 3 or 4 in each cavity, while in most of the species only one or two. The type was collected by Drummond in Texas.

TEXAS: *Drummond 140;* Dallas, *Reverchon 263; 243; 594* (Curtis' no.); Manor, *E. Hall 151;* Austin, *Young*, in 1914.

2. **Hesperastragalus oxyrhynchus** (Hemsley) Rydb. *Astragalus oxyrhynchus* Hemsley, Biol. Cent. Am. Bot. **1:** 265. 1878. The type was collected at Tizapan, as given by Hemsley, or Zapan as given on the label, in the Federal District of Mexico, by Bourgeau (*no. 329*). The isotype of this number in the Gray Herbarium is in flowers only, but the pod is described as being acute. Good fruiting specimens are represented by *Pringle 9722*, and correctly labeled. Jones described *A. angelinus* from specimens from near San Angel in the valley of Mexico, *Rose and Painter 6490*. This I am inclined to refer here. Jones described the fruit as being "obtuse or a little retuse." In the isotype in the herbarium of the New York Botanical Garden, some of the pods are decidedly acute, while others are obtuse and mucronate.

The latter are evidently not normal. In another number of *A. angelinus*, cited by Jones, *Rose & Painter 7090*, the pods are exactly like those of *Pringle 9722*. Jones placed *A. angelinus* next to *A. diphacus*, while he placed *A. oxyrhynchus* in the MICRANTHI. They are evidently the same.

MEXICO (Federal District): Zapan, *Bourgeau 329;* San Angel, *Rose & Painter 6490.*—HIDALGO: El Salto, *Pringle 9722;* Tula, *6404. Rose & Painter 7090.*

DIPHACI

Pod strigulose, subsessile; leaflets linear, obtuse or acutish..... 3. *H. diphacus*
Pod glabrous, distinctly stipitate, the stipe about equalling the calyx; leaflets obovate, retuse..... 4. *H. brazoensis*

3. **Hesperastragalus diphacus** (S. Wats.) Rydb. *Astragalus diphacus* S. Wats. Proc. Am. Acad. **17:** 342. 1882. This was described from *Schaffner 816* from San Luis Potosi. It resembles the preceding species a good deal, but the pod is different, being rounded or retuse at the apex, didymous, the axis of the cells forming a straight line.

SAN LUIS POTOSI: *Schaffner 612/816.*—ZACATECAS: *Pringle 1753.*—MEXICO: [without locality] *Woelfflin*, in 1845.—JALISCO: Constancia, *Pringle 11362.*

4. **Hesperastragalus brazoensis** (Buckley) Rydb. *Astragalus brazoensis* Buckley, Proc. Acad. Phila. II. **5:** 452. 1861. This species resembles *H. reflexus* in habit but the pod is distinctly stipitate and broader than long. The type came from "Western Texas" [more properly Eastern Texas, if it was named for Brazos River.]

TEXAS: *Buckley;* Corpus Cristi Bay, *Heller 1483;* Valley of the Nueces, *Majôr Thomas; Palmer 244;* Eagle Pass, *H. C. Hanson 690;* San Antonio *Rockwell*, in 1912.—TAMAULIPAS: Matamoras, *Tracy 9091.*

DIDYMOCARPI

Calyx white-hairy.
Pod short pubescent, strongly rugose; leaflets more or less cuneate, deeply retuse..... 5. *H. dispermus*
Pod glabrous, not strongly rugose, leaflets oblong, not retuse. 6. *H. obispensis*
Calyx black-hairy.
Pod pubescent; corolla less than 7 mm. long.

Leaflets oblong or cuneate, not deeply emarginate.
Pod densely pubescent with appressed hairs, not strongly rugose; racemes elongate, linear..... 7. *H. Elmeri*
Pod with spreading pubescence; raceme short, rounded to oblong.
Pod rather densely long-hairy; corolla 4–5 mm. long.
Flowers subsessile in a dense head; pod not reflexed. 8. *H. compactus*
Flowers short pedicelled; raceme in fruit slightly elongate; pod reflexed..... 9. *H. Gambellianus*
Pod short-pubescent; corolla 6–7 mm. long.....10. *H. didymocarpus*
Leaflets linear, usually deeply emarginate.....12. *H. catalinensis*
Pod glabrous, corolla about 10 mm. long.....11. *H. Milesianus*

5. HESPERASTRAGALUS DISPERMUS (A. Gray) Heller. Jones in his Revision distinguished this species from *H. didymocarpus* by the pod, which according to him is "3-3 [evidently he means 3–4] mm. long, with cross-section flatly triquetrous-cordate" in the former, and "*3 mm.* long, with cross-section a crescent," in the latter. He figured both as obcordate, but that of *A. dispermus* slightly more broadly so. In fact there is little difference in the fruit, though that of *H. didymocarpus* is somewhat broader. In *H. dispermus* the calyx is white-hairy with shorter teeth and the leaflets comparatively shorter and broader; in *H. didymocarpus* the calyx is black-hairy especially when young.

ARIZONA: Wickerberg, *Palmer* (type); Apache Gap, *Lemmon 606;* Verde River, *Smart 150;* Tucson, *Griffiths 3638;* Mohave Desert, *Lemmon*, in 1884.—CALIFORNIA: San Diego County, *Pringle*, in 1882; *Abrams 3568;* San Filipe, *Brandegee*, in 1891; Elsenor, *MacClatchie;* Palm Springs; *Grant*, in 1906; *Eastwood 2601; 3058;* Cariso Creek, *Brandegee*, in 1905; San Bernadino County, *Parish 19242; Purpus 5553;* Warner's Hot Springs, *Eastwood 2601;* Palm Spring, *H. M. Hall 5763.*—LOWER CALIFORNIA: Hansen's, *Orcutt;* Todos Santos Bay, *Jones*, in 1882.

6. **Hesperastragalus obispensis** Rydb., sp. nov. An annual; stem 1 dm. high, branched at the base, the branches ascending or spreading, minutely strigose; leaves 2–3 cm. long, spreading; stipules herbaceous, deltoid, acuminate, 2 mm. long; leaflets 9–11, elliptic or oblong, mostly rounded at the apex, 4–5 mm. long, pilose on both sides; peduncles 2–4 cm. long, slender; raceme dense, head-like, 1.5–2 cm. long, 1.5 cm. in diameter, bracts subulate, 2–3 mm. long; flowers nearly sessile; calyx white-pilose, the tube broadly campanulate, 2 mm. long, the teeth subulate, 2 mm. long; corolla apparently white with purple-tipped keel, 5–6 mm.

long; banner with an oval blade, strongly arcuate; wings shorter, the blades obliquely oblanceolate; keel-petals nearly as long, the blade lunate, strongly arched at the middle, attenuate at the apex; pod glabrous, 3 mm. long, about as broad, 2 mm. deep, broadly ovate when seen from above, glabrous, acute.

The type was collected at San Luis Obispo, California, May 6, 1882, *Jones 3229* (in part, herb. N. Y. Bot. Gard.). The sheet contains 3 specimens. It was first labeled *Astragalus didymocarpus*, then corrected to *A. dispermus*. The lower two specimens belong to this species, the upper and larger one is a specimen of *H. Gambellianus*. Two other sheets of the same number are also in the herbarium of the New York Botanical Garden. Jones has corrected the determination of one to *A. dispermus*, the other to *A. nigrescens*. Both represent *H. Gambellianus;* so also the sheet in the National Herbarium.

7. **Hesperastragalus Elmeri** (Greene) Rydb. *Astragalus Elmeri* Greene, Erythea **3**: 98. 1895. This differs from its closest relatives in the more elongate inflorescence and its appressed-hairy fruit. To it belongs the following specimens:

CALIFORNIA: Ros Valley, *Elmer Drew* (type); Stanford University, *Baker 718* (determined as *A. catalinensis*); *Heller 7357* (as *A. nigrescens*); *Elmer 4636* (as *A. didymocarpus*).

8. HESPERASTRAGALUS COMPACTUS Heller. Jones reduced this to a synonym of *A. dispermus*, but it is evidently closer to *H. Gambellianus* (*A. nigrescens* Nutt.), having the black-hairy calyx. I have seen specimens only of the type collection, *Heller 8156*, from Pollasky, Fresno County, California.

9. HESPERASTRAGALUS GAMBELLIANUS (Sheldon) Heller. This was first described as *Astragalus nigrescens* Nutt., but the name was changed to *A. Gambellianus* by Sheldon, as there was an older *A. nigrescens* Pallas.

OREGON: Ashland, *Howell*, in 1899.—CALIFORNIA: numerous specimens.—LOWER CALIFORNIA: Encenada, *Jones*, in 1882.

10. HESPERASTRAGALUS DIDYMOCARPUS (H. & A.) Heller. This is well understood.

CALIFORNIA: *Douglas;* Santa Barbara, *Elmer 3838; Tracy;* San Joaquin County, *Baker 2782;* Kern County, *Heller 7600;* Antioch, *Brandegee;* Mojave, *Mrs. DeKalb;* San Clemente Island,

Trask 206; San Bernadino Co., *Parish 5560;* San Joaquin Valley, *Burtt Davis 3062.*

11. **Hesperastragalus Milesianus** Rydb., sp. nov. Annual; stem erect, 2–3 dm. high, glabrous or with a few scattered hairs; leaves 4–6 cm. long, ascending; stipules 2–3 mm. long, deltoid, more or less scarious; leaflets 11–13, oblong-cuneate, about 1 cm. long and 2 mm. wide, emarginate, glabrous above, sparingly hairy beneath; peduncles 4–5 cm. long; raceme head-like, dense, 1–2 cm. long, fully 1 cm. broad; bracts lanceolate, 1–2 mm. long; flowers subsessile; calyx black-hairy, the tube 2–2.5 mm. long, the teeth subulate, fully 1 mm. long; corolla purplish; banner oblanceolate, 1 cm. long, emarginate; wings about 8 mm. long, the blade oblanceolate, with a large reflexed auricle; keel-petals about as long, the blade strongly arcuate near the rounded apex, with a small auricle; pod rounded ovoid, strongly cross-ribbed, glabrous, 4 mm. long, nearly as thick and broad, broadly obcordate in cross-section.

Type collected at San Luis Obispo, California, April 1886, *M. M. Miles* (herb. N. Y. Bot. Gard.).

12. **Hesperastragalus catalinensis** (Nutt.) Rydb. *Astragalus catalinensis* Nutt. Proc. Acad. Phila. **4:** 9. 1848. This species has usually been regarded as the same as *Astragalus didymocarpus* H. & A., but differs in the narrow linear leaflets, deeply emarginate at the apex; and in the hairs of the pod, which are at least twice as long. The corolla is usually smaller.

California: San Diego County, *Orcutt,* in 1884; *W. S. Brown; M. E. Jones 3152; Abrams 3517.*—Lower California: San Quentin Bay, *Palmer 614.*

INDEX TO AMERICAN BOTANICAL LITERATURE
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